1,048,122

PATENT SPECIFICATION

DRAWINGS ATTACHED

1,048,122

Date of filing Complete Specification (under Section 3 (3) of the Patents Act 1949) May 8, 1963.

Application Date: Feb. 9, 1962. No. 5059/62.

Application Date: Oct. 30, 1962. No. 40991/62.

Complete Specification Published: Nov. 9, 1966.

Index at acceptance:—F4 S(4B, 4E, 4G)

Int. Cl.:—F 25 h

COMPLETE SPECIFICATION

Improvements in and relating to Plate Type Heat Exchangers

I, TERENCE PETER NICHOLSON of Craigmillar, Stocksfield, in the County of Northumberland, a British Subject, do hereby declare the invention, for which I pray that a Patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to heat exchangers of the type wherein parallel channels for the flow of two fluids between which heat exchange is to occur are provided in honeycomb form and separated by a plurality of plates (hereinafter called "a heat exchanger of the stated type").

An object of the invention is to provide improved forms of heat exchangers in which corrugated plates are adapted for stacking, with the aid of marginal spacer strips if required, so that each plate constitutes a primary element for exchange of heat between the two fluids passing one on each side of the plate. The plates of a heat exchanger provided by the invention are thereby distinguished from many types of corrugated plate known in the art, which serve as secondary heat exchange elements, the function of which is solely to conduct heat from one fluid passing on both sides of the corrugated plate to flat plates between opposed faces of which the corrugated plate is sandwiched, said flat plates serving as the primary heat exchange elements between said one fluid and another fluid passing on both sides of further corrugated plates in contact with the other faces of said flat plates.

According to the invention, a heat exchanger of the stated type comprises a series of plates serving as primary heat exchange elements and stacked to provide a plurality of alternate passages for respective ones of the two fluids, each plate having a series of corrugations integrally formed in it to extend parallel to a pair of mutually parallel longitudinal margins of the plate and said corrugations defining a median plane of the plate to opposite sides of which plane alternate half waves of the corrugations project, the corrugations terminating at respective lines short of end margins of the plate which end margins extend between said longitudinal margins, the margins of said terminating lines together defining respective triangular end zones of the plate, fluid inlets to and outlets from said alternate passages being provided at the margins bounding said zones.

The corrugations in transverse section may be sinusoidal, or may be trapezoidal so that the longitudinal passages, provided by butting together two plates, are hexagonal. In each plate such continuous corrugations may terminate at each end on a line which is perpendicular to their length and the plate may have the form of a trapezium or parallelogram the ends of which provide the triangular end zones. Alternatively, in a rectangular plate, continuous corrugations may terminate on a line which is oblique to their length, so as to leave the triangular end zones.

In a preferred form of corrugated plate which affords better resistance to possible deformation of the plate when the fluids on opposite sides of each plate are under widely different pressures, in the zones at each end of the plate embossments may be formed on one side of said median plane at both ends.

Said embossments may be thimbles, the term "thimble" being intended to define an individual embossment which is conical,

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pyramidal, semi-ovoid or hemi-spherical or a short length of a corrugation, or the like, in the material of the plate, rising from a base located at said median plane. A plurality of such thimbles may be formed in line with some of the ranks of continuous corrugations so as to extend across a zone at the end of the plate. Alternatively, short corrugations in the end zone may extend in arcuate *loci* from one lateral margin of said zone, tending towards the longitudinal direction nearer to the ends of the continuous longitudinal corrugations.

As seen in the direction of the length of a corrugation, the series of thimbles may have the same cross-section as the corrugation. For example, where the corrugations are trapezoidal so that a plurality of juxtaposed plates form a true honeycomb structure with hexagonal passages, the thimbles may be conical with flat tops, and may be four- or six-sided. The thimbles need not, however, have the same cross-section as the corrugations, and for simplicity of manufacture may be part-spherical or part-ovoid, or conical with flat or rounded tops.

In an alternative construction of heat exchanger according to the invention, each plate may be of rectangular form and be provided with an oblique band of continuous longitudinal corrugations the triangular end zones being planar and located in the median plane, corresponding triangular portions of wholly corrugated sheet metal being welded to the surfaces of said planar end zones. Evidently, said triangular portions will be disposed with their corrugations extending longitudinally to provide end inlet and outlet channels, and extending transversely to provide lateral outlet channels, when said plane end zones have the form of right-angled isosceles triangles, identical triangular corrugated portions may be employed, and simply disposed before welding with their corrugations extending longitudinally or laterally.

In the construction of a heat exchanger with corrugated plates as aforesaid, such plates may be assembled in juxtaposition with their opposed corrugations in mutual lengthwise contact, spacer elements having a thickness equal to the total depth of corrugation of one plate being interposed between flat marginal portions of said plates.

Another mode of assembly of a heat exchanger according to the invention may be afforded by using plates embossed as aforesaid, each of which is quadrilateral and has a first margin bent through two equal and opposite angles to provide a narrow marginal strip with a surface in the plane of the apices of the embossments on one side, the opposite second margin bent to provide a similarly located and wider marginal strip adapted to be clenched round a narrow first marginal strip of a juxtaposed like plate on said one side, a third margin transverse to said first and second margins likewise bent to provide a narrow marginal strip with a surface in the plane of the apices of the embossments on the other side, and the fourth margin opposite said third margin bent to provide a similarly located and wider marginal strip adapted to be clenched round a narrow third marginal strip of a juxtaposed like plate on said other side.

Another object of the present invention is to provide adaptations of the plates as aforesaid more particularly for the production of annular heat exchangers, wherein the median plane of each plate is radial or substantially radial to the axis of the heat exchanger.

To this end, the invention further provides plates as aforesaid wherein the depth of the corrugations and/or other embossments increases progressively from one end to the other of each plate. Since in an annular heat exchanger there may be a very large number of plates, for example, 300—400, the progressive increase of depth may be very slight, and equivalent to an angle of no more than 2°.

Various embodiments of heat exchanger plates, and of heat exchangers constructed therefrom, in accordance with the invention, will be described by way of example with reference to the accompanying diagrammatic drawings, wherein:—

Fig. 1 is an exploded view of a group of plates and spacers,

Fig. 2 is a lateral view of the same assembled,

Fig. 3 is a transverse section, on an enlarged scale, on the lines III—III of Figs. 1 and 2,

Figs. 4 and 5 are face views of two alternative forms of plate,

Fig. 6 is a longitudinal section on the line VI—VI of Fig. 5,

Fig. 7 is an exploded view of components of another form of plate, and

Fig. 8 is a perspective view, partly in section, showing a modified plate affording an alternative mode of assembly,

Fig. 9 is a diametrical section of an annular heat exchanger, and

Fig. 10 is a flow diagram of a gas turbine incorporating an annular heat exchanger.

Figs. 1—3 of the drawings show two variants of an embossed heat exchanger plate according to the invention, assembled as the first pair of a regular series with a flat back plate. As shown in Fig. 2, the spaces between each two plates may be tapered so that the heat exchanger has a sector form capable of association with others into a completely annular heat exchanger as will hereinafter be described. As

an alternative, the plates may be parallel so that the heat exchanger unit is a cuboid block.

Each of the plates 1 and 2 is rectangular, and has a series of longitudinal corrugations 3 extending across the width of the plate and terminating at oblique lines 4 extending approximately from adjacent diagonally opposite corners of the plate, so as to leave triangular end zones 5 with their apices at said opposite corners. In each of the plates 2 and 3 the corrugations may be of any suitable form which at any transverse line project equally and alternately on opposite sides of the median plane of the plate. The corrugations may be triangular so that when two plates are abutted they afford diamond section passages, or may be trapezoidal to afford hexagonal passages, or may be sinusoidal so that the passages are approximately circular.

In the plate 1, which is intended to provide a longitudinal pass for fluid between end inlet and outlet openings, in each end zone 5 the plate is embossed on one side with short longitudinal corrugations 6. These short corrugations have a height equal to the total height of the corrugations 3 on both sides of the plate 1, so that in a series of alternate plates 1 and 2 the corrugations 6 support the end zone of the overlying plate. Thus, as shown in Fig. 3, the corrugations 6 of the plate 1*a* abut and support a flat back plate 7, while the corrugations 6 of plate 1*b* abut and support portions of the end zones 5 of the overlying plate 2*a*.

In the plate 2 as shown in Fig. 1, which is intended to provide a longitudinal pass for fluid between lateral inlet and outlet openings, each end zone 5 is provided with short corrugations including arcuate corrugations 8 which serve to divert fluid from the longitudinal to the lateral course, or *vice versa*, and transverse straight corrugations 9 which direct the fluid laterally. Like the corrugations 6 in the end zones of the plate 1, the corrugations 8 and 9 of the plate 2 have a height equal to the total height of the corrugations 3 on both sides of the same plate 2; thus, as seen in Fig. 3, the corrugations 8 (which are shown) partly in transverse section and partly in elevation) and the corrugations 9 (which are shown in transverse section) of the plates 2*a* and 2*b* respectively abut and support the end zones of the overlying plates 1*a* and 1*b*.

In the assembly of alternate plates 1 and 2 and the flat back plate 7, spacing strips are suitably located between portions of the margins of the several plates. Where end inlet and outlet openings are to be provided, as between the plates 1*a* and 7 and the plates 1*b* and 2*a* in Fig. 3, and also of course between the plate 2*b* and the underlying plate of the series 1 and so on, the spacer strips 10 are straight and extend along the full length of both sides of the two plates. Where lateral inlet and outlet openings are to be provided, as between the plates 1*a*, 2*a* and 1*b*, 2*b* in Fig. 3, the spacer strips 11 are of L-form so that each extends across the margins of one end of the pair of plates, and from the corner of each plate which is closely approached by the corrugations 3 along one side of the plate to the other end of the adjacent corrugation, so as to leave open the side of each triagular end zone 5.

For supporting the margins of the plates at the inlet and outlet openings, they are provided across each of these openings with a series of punched-out arch-form projections 12, in each plate on the side opposite the projection 6 or 8, 9 respectively in the end zones, as shown, for example, in Fig. 3 on the plates 1*a* and 1*b* wherein these projections 12 are located at the sides of the triangular end zones. Likewise in the plates 2 the arch-form projections 12 are located across the end margins of the end zones 5 to support end inlet and outlet openings. These punched-out arch projections afford very little restriction of the area of the opening, since only the edges of said arched portions are presented to the flow of fluid, which can pass inside as well as outside the arches.

When a mode of assembly of the plates with spacer strips as described is employed for the construction of a sector form heat exchanger unit, or a completely annular heat exchanger, it is not necessary that each of the plates should be strictly in a plane radial to the axis of said unit or heat exchanger. This enables the avoidance of a disadvantage which would follow from the necessity to make the L-form spacer strips 11 with tapering thickness if the plates 1 and 2 between which they are located were to be mutually inclined as shown in Fig. 2. Assuming that the angle between the underside of the plate 7 and the underside of the nearest plate 2 were to be 4°, while maintaining this angularity between the plates 7 and 2, the intermediate plate 1 may be located parallel to the plate 2 by the provision of L-form spacers 11 having uniform thickness, the radially extending straight spacer strips 10 between the plates 1 and 7 having said taper of 4°.

Fig. 4 shows another form of heat exchanger plate 14 according to the invention, having a similar oblique band 3 of corrugations and triangular end zones 5 in which are located longitudinally and transversely extending ranks of thimbles 15. Since this arrangement of thimbles (which may be regarded as interrupted corruga-

tions) will permit flow of fluid either longitudinally or laterally, a heat exchanger having end inlet and outlet openings for one fluid and lateral inlet and outlet openings for another fluid may be constructed from an assembly of one single type of plate 14. The thimbles 15 may be made to project alternately on opposite sides of the plate 14, and have sections equivalent to the section of half of one of the corrugations 3. Alternatively said thimbles may be made entirely on one side of the plate and have a height equal to the total height of the corrugations 3 on both sides of the plate (like the short corrugations 6, or 8, 9 of the plates 1 and 2 as shown in Fig. 3); in this latter case it may be desirable to provide on each plate 14 a series of arch-form projections 12 as shown in Fig. 4 extending across the intended inlet or outlet opening. However, as this necessitates ultimately two differently finished types of plate 14, the arrangement as mentioned of the thimbles 15 alternately on opposite sides of the plate is preferable, since those thimbles can extend to the margin of the opening, whether end or lateral, and the mutual abutment of thimbles on two adjacent plates supports them across this opening.

Figs. 5 and 6 show yet another form of plate 18 having an oblique series of longitudinal corrugations 3, and triangular end zones which are wholly occupied by transversely extending corrugations 19. As shown more clearly in Fig. 6, to construct a heat exchanger unit from plates of this kind it is necessary to assemble the plates 18, in each of which the transverse corrugations 19 are located on one side of the plane of the margins and have a height equal to the total depth of the corrugations 3 on both sides of the plate, in alternation with plates 17 (Fig. 6) which have similar longitudinal corrugations but no corrugations in their end zones. Thus, when the plates 17, 18 are assembled into a unit with pairs alternately of L-form spacer strips 11 across the transverse margins 21 and along parts of the lateral margins 20 between those sides of the plates from which the transverse corrugations 19 project, and straight spacer strips 10 between the other pairs of plates, the unit is adapted to provide alternate passes for one fluid with end inlet and outlet openings, and passes for the other fluid with lateral inlet and outlet openings between the flat end portions of plates 17 and the transversely corrugated portions 19 of the plates 18. In order to support the margins of the inlet and outlet openings the plates 17, 18 may be provided, like the plates 1 and 2 of Fig. 1, with punched-out arch-form projections 12 suitably located and as above described.

In order to avoid the necessity for providing two different plates, such as the plates 1 and 2 of Figs. 1 and 3 or the plates 17, 18 of Fig. 6, the alternative may be adopted of providing as shown in Fig. 7 a single form of basic plate 22 (which is the equivalent of plate 17) provided with an oblique band of corrugations alternately projecting on both sides of the plate and terminating at lines which are at an angle of 45° to the length of the plate, leaving plane end zones 25 each of which has the form of a right-angled isosceles triangle. Corresponding triangular portions 26 of wholly corrugated sheet metal are welded to the surface of the plane end zones 25. As indicated in Fig. 7, on alternate plates 22 of a pack, said triangular portions 26 are disposed with their corrugations extending longitudinally to provide end inlet and outlet openings. On the corresponding side of an adjacent plate triangular portions 26*a* are disposed with their corrugations extending transversely to provide lateral inlet and outlet openings. The total height of the corrugations in the portions 26, 26*a*, is equal to the projections of the corrugations 23 from the surfaces of both sides of the plate 22, so that when two plates are abutted the mutually registering longitudinally extending corrugations 23 are in contact at their ridges, and the longitudinally and transversely corrugated portions 26 and 26*a*, support the superposed plane surfaces of the end zones of the plates 22. A plurality of plates 22 thus arranged can be assembled into a heat exchanger unit with the aid alternately of longitudinal spacer strips 10 and L-form spacer strips 11 as described with reference to Figs. 1—3.

In the construction of heat exchangers or units thereof with plates and spacer strips as hereinbefore described, after assembly in a suitable jig the components can be permanently united by soldering or brazing over the areas where the sides of the spacer strips 10, 11 are superposed.

Fig. 8 illustrates an alternative mode of securing plates together in a unit. In this arrangement each plate 27 has a rectangular portion provided with an oblique band of corrugations as in Fig. 7 with or without triangular corrugated end portions 26, 26*a*. Each plate 27 has one longitudinal margin bent through two equal and opposite angles to provide a narrow marginal strip 28 with a surface 29 in the plane of the ridges of the corrugations 23 on one side of the plate, and the opposite margin bent to provide a similarly located and wider marginal strip 30 doubled inwards upon itself to provide a U-form bead adapted to be clamped around a narrow longitudinal marginal strip 28 of a juxtaposed like plate on said one side. Each plate 27 also has a transverse margin 31 likewise bent to provide a narrow marginal

strip with a surface in the plane or the ridges of the corrugations 23 on the other side of the plate, and its other, opposite transverse margin bent to provide a similarly located and wider marginal strip 32 doubled back upon itself to provide a U-form bead adapted to be clenched round the narrow transverse marginal strip 31 of an adjacent plate as shown at the ends of the assembly of two plates in Fig. 8. Evidently pairs of plates thus formed may be continued to provide a sectorial exchanger unit or a complete annular heat exchanger when the corrugations and margins of the plates are suitably pressed up so that each two adjacent plates are at a slight mutual inclination.

The arrangement as described with reference to Fig. 8 necessitates the provision of right and left-handed variants of the plate 27. Since it is necessary to provide two variants of this plate it may be preferable to form one variant with two U-form beads 30 along its longitudinal margins and two plane marginal strips 31 across its transverse margins, and the other variant with two narrow longitudinal marginal strips 28 and two beads 32 transversely across its ends. Hereby the two variants are made easily distinguishable. The plates can then be assembled in succession by sliding the longitudinal margins 28 of a second plate into the beaded margins 30 of a first plate, the transverse margins 31 of a third plate into the beaded transverse margins 32 of said second plate and so on.

Evidently, any two plates united at their longitudinal margins will afford end inlet and outlet openings, and each two plates united by their transverse margins will afford lateral inlet and outlet openings. An assembly of plates as described may be completed in a cuboid block by a square section bar 33 soldered or brazed into each corner; in an annular heat exchanger of similar construction, the bars 33 are replaced by rings having the same square section. In order to close portions of the sides of the assembly which are not required for lateral entry and discharge of fluid, strips 34 of rectangular section can be soldered or brazed into the adjacent margins of the plates.

An annular heat exchanger according to the invention may be mounted upon the end of a circular duct in a transverse disposition, by one edge of its inner surface, there being secured to the other edge of said inner surface a conical or annularly concave divertor, symmetrical about the axis of the duct, for closing the duct and directing the fluid from it radially outwards into the open inner ends of the alternate radial channels between the plates of the heat exchanger. The other fluid may flow in a concentric duct, the end of which communicates with lateral inlet openings at one side of the annular heat exchanger, and the fluid issuing from the alternate lateral outlets between the plates at the other side may be transported therefrom within another duct connected to said other side of the heat exchanger, or collected in a suitable manifold. The fluid issuing from the outer ends of the radial channels in the heat exchanger may be discharged to atmosphere or collected in a suitable annular or spiral manifold.

In a modification of this arrangement, two like annular heat exchanger units may be connected together co-axially by spacer rings secured between the adjacent inner and outer margins of their opposed transverse surfaces. Their outer or inner annular surfaces may be enclosed within a semi-toroidal member which serves to divert fluid passing outwardly or inwardly through alternate radial channels in one unit through 180° to pass inwardly or outwardly through alternate radial channels of the other unit. The axially flowing fluid passes through intermediate channels with lateral inlet and outlet openings in the two units successively. The fluid flowing radially through the heat exchangers may be supplied and discharged in a co-axial duct so that the two fluids flow in the same or opposite axial directions, one within an inner duct, and the other in an annular channel defined by the outer surface to said inner duct and a concentric outer duct. Alternatively, either fluid after passing through the pair of heat exchangers may be exhausted to atmosphere.

In an embodiment of heat exchanger as last recited, and as illustrated in Fig. 9, two annular plate assemblies 35, 36 are enclosed within a casing 37 which affords firstly for one fluid two aligned co-axial ducts 38, 39 the ends of which are separated so that said one fluid passes radially outwards through the assembly 35 and inwards through the other assembly 36; secondly a substantially semi-toroidal diverting chamber 40 enclosing the outer annular surfaces of the two assemblies; and thirdly a pair of wedge-form manifolds 41, 42 affording for the other fluid entry to and discharge from inlet and outlet openings at the ends of the two assemblies, which said other fluid enters and leaves longitudinally, the wider ends 43, 44 of these wedge-form manifolds being open and flanged for attachment to suitable ducts.

The casing 37 may for example be die-cast in two identical parts, divided on a transverse plane of said diverting chamber 40 with external flanges 45 whereby the two parts may be bolted together to enclose the duplex heat exchanger.

The separator for the two aligned co-axial ducts 38, 39 is a circular element 46

each end face of which is quadrantally concave in radial section, with a central point axially directed, so that the fluid flowing in said co-axial ducts is smoothly diverted first from the axial to the radially outward direction, and secondly from the radially inward again to the axial direction. The median rim of said element has a flange which is inserted between the adjacent inner margins of the two plate assemblies 35, 36 and a seal ring 48 is inserted between the corresponding, adjacent outer margins of said assemblies. These are pressed against opposite sides of said flange and seal ring by the bolting together of the half parts of casing 37, which have annular shoulders 49 to locate the mutually remoter ends of the assemblies.

The wedge-form manifolds 41, 42 open to said remoter ends of the duplex heat exchanger provide annular chambers, each of which becomes narrower as it is more remote from the lateral, open end 43, 44 of the manifold, thereby to promote even distribution of the fluid entering and leaving by way of said manifolds around the annular series of lateral inlets and outlets afforded by the heat exchanger.

The two plate assemblies of such duplex heat exchanger need not have the same axial length. The assembly 35 through which the fluid passes radially in a relatively hotter state may have a greater length than the other which the same fluid enters radially after having been partially cooled and thus reduced in volume. In this arrangement, the separator 46 is displaced to the cooler side from the plane of symmetry of the semi-toroidal chamber.

An alternative form of annular heat exchanger according to the invention may be constructed of plates each having a middle zone of continuous corrugations extending in the radial direction of each plate. In a heat exchanger thus constructed, the assembly may be regarded as comprising three annular zones, namely an intermediate zone extending throughout the area of continuous corrugation of the plates, which provides the main heat exchange portion for co-current or counter-current fluid flow; and two end portions in each of which the termination or interruption of the corrugations enables both fluids to enter and leave alternate passages laterally, or one fluid to enter and leave laterally while the other fluid enters and leaves radially.

In a construction embodying the latter arrangement, for example, as shown applied to a gas turbine in Fig. 10, each of the plates of an annular heat exchanger 50 may have said intermediate zone defined by radial corrugations in the plates of the kind illustrated in any of Figs. 1, 4, 7 or 8, so as to provide right- and left-handed end zones 51, 52 which are triangular in radial section. The plates are separated by spacers so as to afford radial passages from end to end between alternate pairs of plates, with intervening passages wherein fluid is caused to enter at a lateral margin of said end zone 51, is diverted radially through the corrugated intermediate zone, and is again diverted into a longitudinal direction to be discharged at the opposite lateral margin of the other triangular end zone 52. The lateral openings of said alternate passages may be enclosed within suitable annular manifolds, or one of them, and one of the sets of radials openings may not be enclosed, so as to afford entry or discharge of the relevant fluid from or to atmosphere.

For example, in a heat exchanger as illustrated, which serves as an air pre-heater for a gas turbine, the lateral annular manifold at the outer margin of the heat exchanger is connected by suitable ducting to the air compressor 53 of the engine, while the other lateral manifold 54 has connected to it the intake ends of the ring of combustion chambers 55. An annular manifold 56 within the inner surface of the annular heat exchanger is connected by suitable ducting 57 to the turbine exhaust 58, and the outer ends 59 of the radial passages in the heat exchanger may be open to atmosphere, so that the exhaust gas passing through said radial passages, after serving to pre-heat the incoming air, is discharged to atmosphere.

For convenience of assembly, an annular heat exchanger as aforesaid may be constructed from portions of sector form, the outer plates of each sector being flat so that when two such plates are abutted together no passage is afforded between them.

Evidently, the invention affords means for the construction of a variety of heat exchangers, not only of annular form, but in various box-like forms. Further, heat exchangers according to the invention may be made in various sizes according to the required duty. For example, an annular air preheater assembly for a gas turbine may be constructed of thin plates having a radial dimension of 6" and an axial dimension of about 2—3", the inner annular surface having a diameter of about 4—12" and the outer annular surface consequently having a diameter of about 16—24". At the other end of the range, a heat exchanger according to the invention may be provided, for example, for preheating of combustion air or condensation of steam in industrial power plant, and may, for example, be made of steel plates of relatively substantial thickness, and have a diameter up to 30 feet; such plates may be made substantially in the manner described with reference to Figs. 1—7, and welded together with suit-

able spacing elements and/or manifolds for the construction of the heat exchangers.

WHAT I CLAIM IS:—

1. A heat exchanger of the stated type, comprising a series of plates serving as primary heat exchange elements and stacked to provide a plurality of alternate passages for respective ones of the two fluids, each plate having a series of corrugations integrally formed in it to extend parallel to a pair of mutually parallel longitudinal margins of the plate and said corrugations defining a median plane of the plate to opposite sides of which plane alternate half waves of the corrugations project, the corrugations terminating at respective lines short of end margins of the plate which end margins extend between said longitudinal margins, the margins and said terminating lines together defining respective triangular end zones of the plate, fluid inlets to and outlets from said alternate passages being provided at the margins bounding said zones.

2. A heat exchanger as claimed in Claim 1 wherein in each plate, said corrugations terminate at respective lines that are mutually parallel.

3. A heat exchanger as claimed in Claim 2, wherein in each plate said corrugations terminate on a line which is perpendicular to their length.

4. A heat exchanger as claimed in Claim 1 or Claim 2 wherein in each plate said corrugations terminate on a line which is oblique to their length.

5. A heat exchanger as claimed in Claim 1 or Claim 2 wherein each plate is rectangular and the corrugations terminate short of each end of the plate on two parallel oblique lines each of which extends from adjacent one end of one of said parallel margins to an intermediate point in the other of said margins.

6. A heat exchanger as claimed in any of Claims 1—5, wherein the plates have formed in and distributed over each of said end zones, on one side of each plate, a plurality of embossments each having a height equal to the total height of said longitudinal corrugations.

7. A heat exchanger as claimed in Claim 6, in which said embossments in the end zones of the plates comprise thimbles as hereinbefore defined, located in ranks aligned with some of said longitudinal corrugations and distributed over the width of the end zone in each plate.

8. A heat exchanger as claimed in Claim 6, wherein in alternate plates said embossments in the end zones are short corrugations disposed in longitudinal ranks distributed over the end zone to extend towards end inlet and outlet openings.

9. A heat exchanger as claimed in Claim 6, wherein in alternate plates said embossments in the end zones are short corrugations, some of which extend in arcuate *loci* from the lateral margin of each of said zones, tending towards the longitudinal direction nearer to the ends of the said longitudinal corrugations, and some of which are disposed transversely to said longitudinal corrugations, to extend towards inlet and outlet openings in said lateral margins.

10. A heat exchanger as claimed in any of Claims 1—5, wherein the plates have over the whole area of their triangular end zones a plurality of transverse corrugations on one side of the plate and having a height equal to the total height of said longitudinal corrugations.

11. A heat exchanger as claimed in any of Claims 1—5, wherein the triangular end zones of each plate are planar and are located in the median plane, and a corresponding triangular portion of wholly corrugated sheet metal being welded to a surface of each of said plane end zones.

12. A heat exchanger as claimed in Claim 11, wherein in each plate said plane end zones are right angled isosceles triangles, and identical triangular corrugated portions are welded to said end zones with their corrugations extending longitudinally to end inlets or outlets or extending transversely to lateral inlets or outlets.

13. A heat exchanger as claimed in any of Claims 1—12, in which each plate is quadrilateral and has a first margin bent through two equal and opposite angles to provide a narrow marginal strip with a surface in the plane of the apices of the embossments on one side, the opposite second margin bent to provide a similarly located and wider marginal strip adapted to be clenched round a narrow first marginal strip of a juxtaposed like plate on said one side, a third margin transverse to said first and second margins likewise bent to provide a narrow marginal strip with a surface in the plane of the apices of the embossments on the other side, and the fourth margin opposite said third margin bent to provide a similarly located and wider marginal strip adapted to be clenched round a narrow third marginal strip of a juxtaposed like plate on said other side.

14. A heat exchanger as claimed in Claim 13 in which the plates are assembled in juxtaposition with their opposed abutments in mutual lengthwise contact, each plate having its first and third narrow marginal strips clenched within the second and fourth wider marginal strips of adjacent plates one on each side, and its second and fourth wider marginal strips clenched about the first and third narrow marginal strips of said adjacent plate.

15. A heat exchanger as claimed in any

of Claims 1—12 in which the plates are assembled in juxtaposition with their opposed longitudinal corrugations in mutual lengthwise contact, spacer elements having a thickness equal to the total embossments of one plate being interposed between flat marginal portions of said corrugated plates.

16. A heat exchanger of annular form constructed as claimed in Claim 14 or 15, wherein the median plane of each plate is substantially radial to the axis of the heat exchanger, each pair of radially disposed spacer elements between alternate pairs of plates being tapered to correspond with the angle between the plates, and of alternating spacer elements disposed parallel to said axis the elements at the outer ends of the plates are proportionately thicker than those at the inner ends of the plates, alternate spaces between the plates being open at their radial sides, and the intervening spaces being open at their inner and outer ends.

17. A heat exchanger of annular form constructed as claimed in Claim 15, having in each group of three plates the two outer plates in planes radial to the axis and the intermediate plate parallel to one of said outer plates; two L-form spacer elements of constant thickness between said parallel plates, one extending across the outer end and partly along one lateral side and the other extending along the inner end and partly along the other lateral side of the space between said parallel plates, to provide lateral inlet and outlet openings for said space, and two straight tapered spacer elements located between the lateral margins of the other two, mutually inclined plates to provide inlet and outlet openings at the ends of said mutually inclined plates.

18. An annular heat exchanger as claimed in Claim 16 or 17, mounted upon the end of a circular duct in a transverse disposition, by one edge of its inner surface, there being secured to the other edge of said inner surface a conical or annularly concave divertor, symmetrical about the axis of the duct, for closing the duct and directing the fluid from it radially outwards into the open inner ends of alternate radial channels between the plates of the heat exchanger, channels for another fluid with lateral inlet and outlet openings being provided in alternation with said radial channels.

19. A modification of the heat exchanger as claimed in Claim 17, comprising two like annular heat exchanger units connected together coaxially by spacer rings secured between the adjacent inner and outer margins of their opposed transverse surfaces, one of their outer and inner annular surfaces being enclosed within a semi-toroidal member which serves to divert one fluid passing radially in one direction through one unit around 180° to pass radially in the opposite direction through the other unit, the other fluid being caused to flow by way of lateral inlet and outlet openings through the two units successively.

20. A heat exchanger as claimed in Claim 19, having aligned coaxial ducts for entry and discharge of said radially flowing fluid and between said ducts a circular separator wall each face of which is formed to divert said fluid between the axial and radial directions.

21. A heat exchanger comprising a plurality of plates as illustrated in Figs. 1 to 8 of the accompanying drawings, and assembled with intermediate spacing elements substantially as hereinbefore described.

22. An annular heat exchanger connected to supply and discharge ducts for two fluids, substantially as hereinbefore described with reference to Fig. 9 or Fig. 10 of the accompanying drawings.

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Leamington Spa: Printed for Her Majesty's Stationery Office by the Courier Press.—1966.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtai

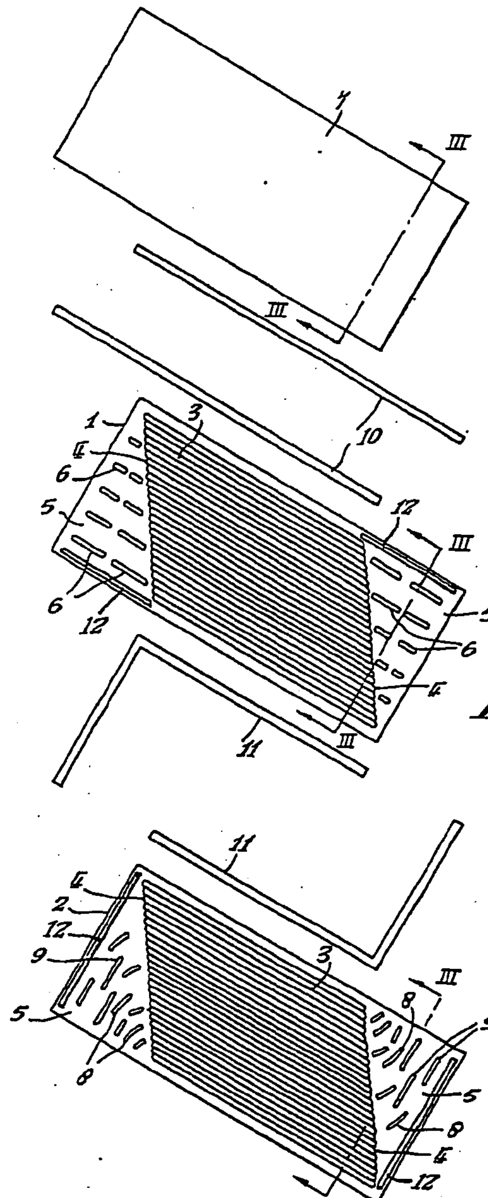
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Fig.1.

1048122 COMPLETE SPECIFICATION

6 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 1 & 2

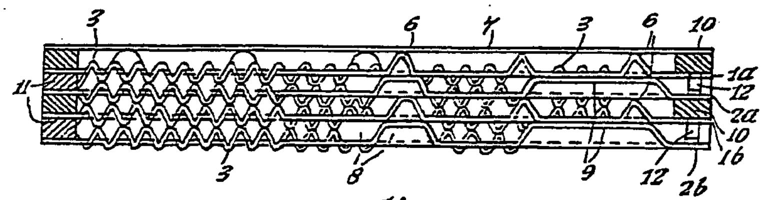


Fig.3.

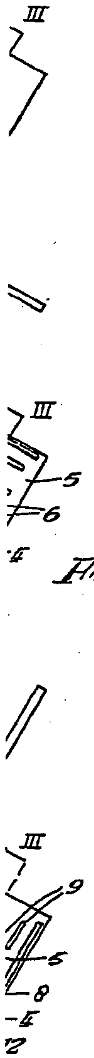


Fig.1.

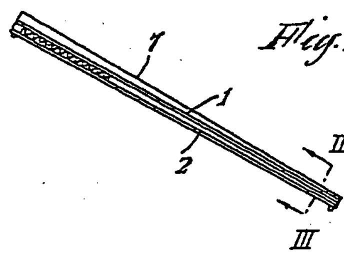
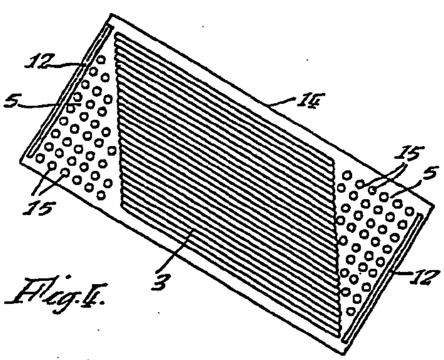


Fig.2.



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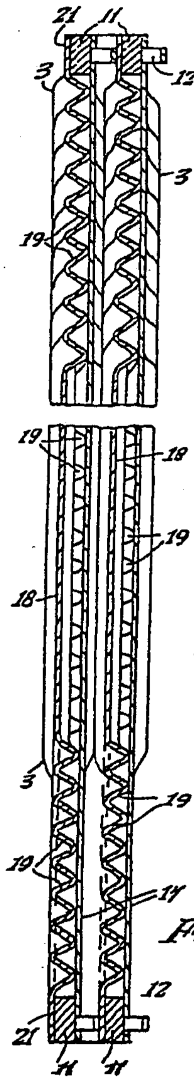

Fig.6.

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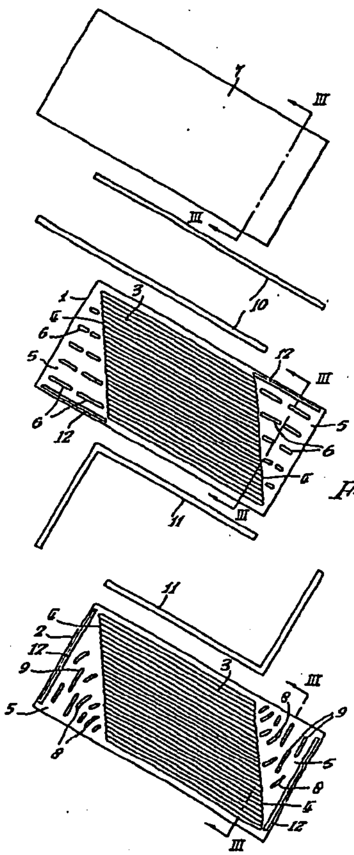

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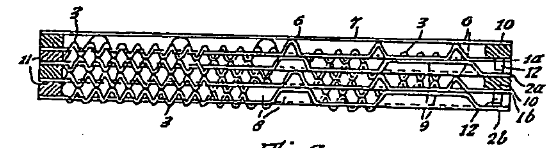

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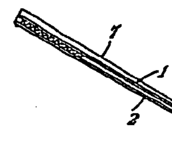

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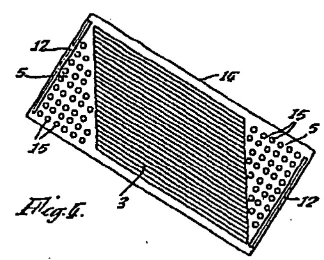

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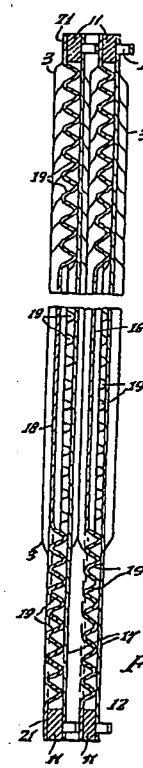

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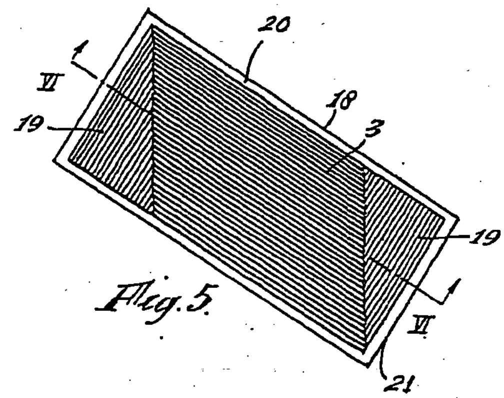

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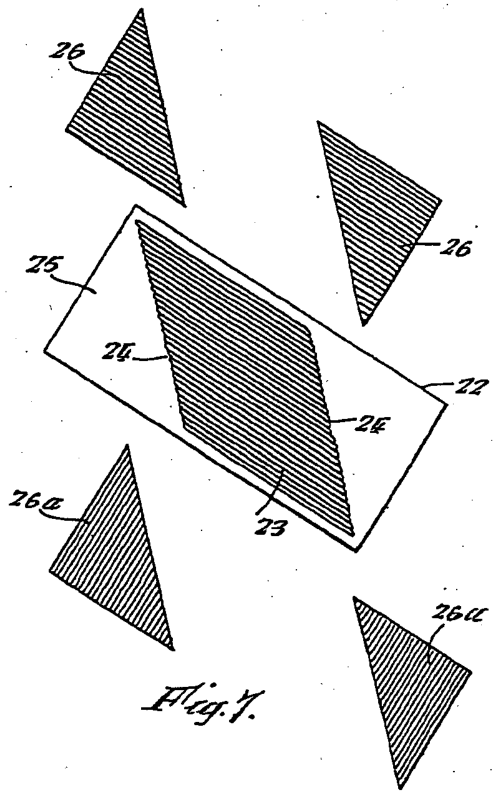

Fig. 7.

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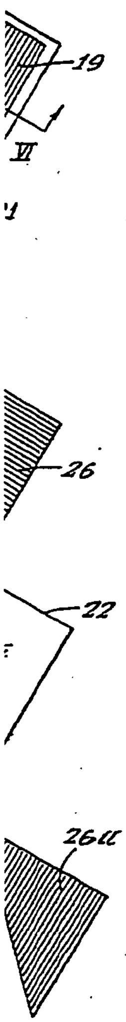
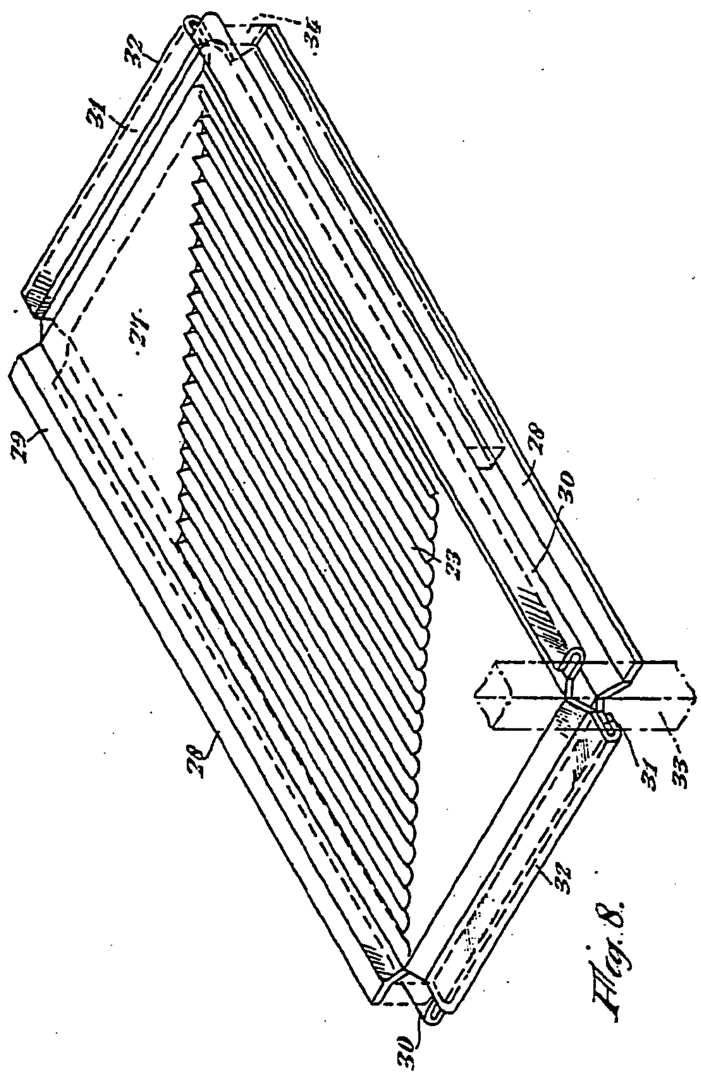
Sheets 3 & 4





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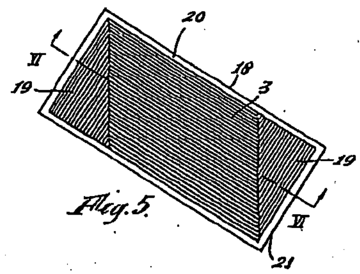

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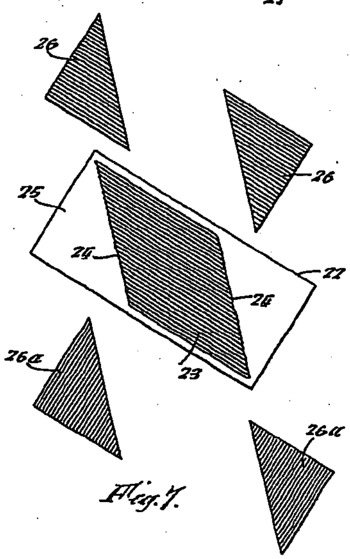

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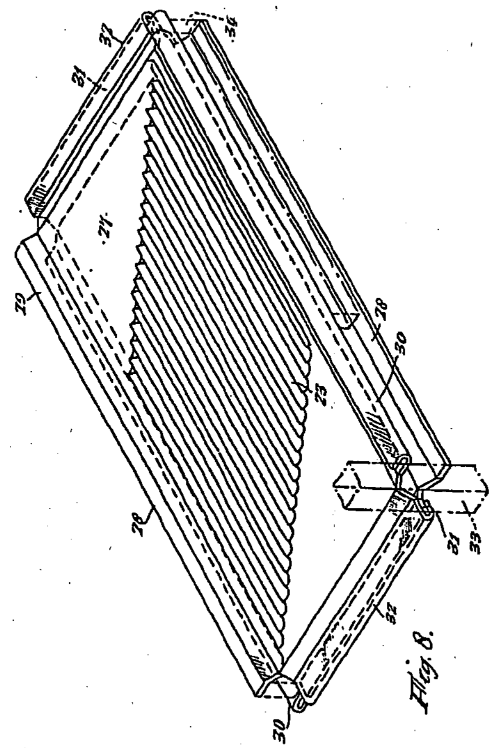

Fig. 8.

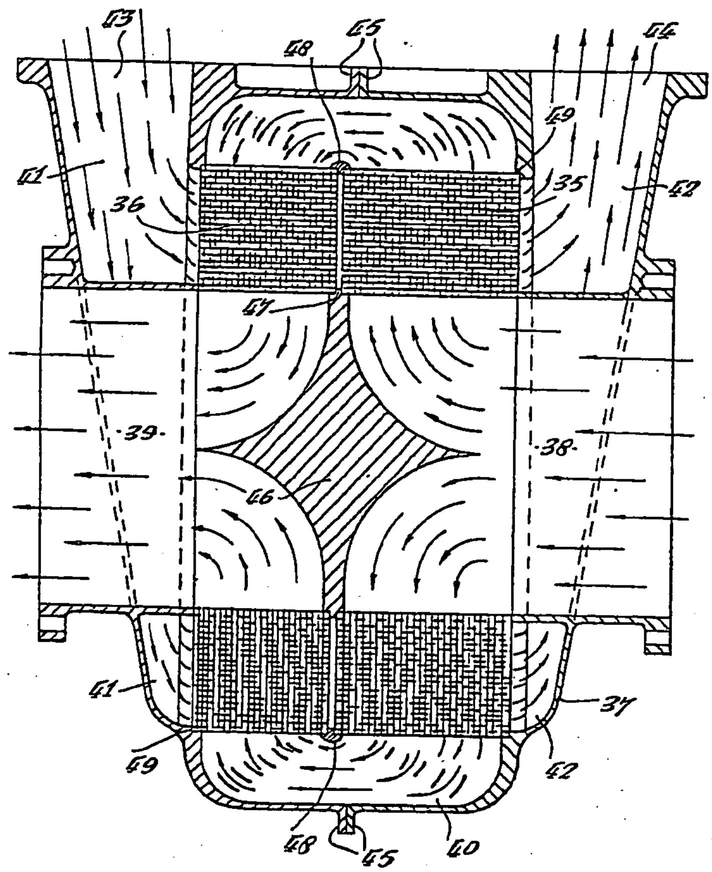

Fig. 9.

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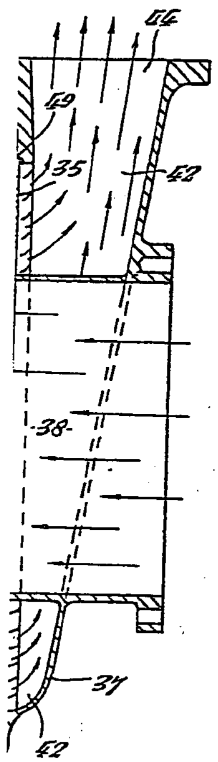
Sheets 5 & 6



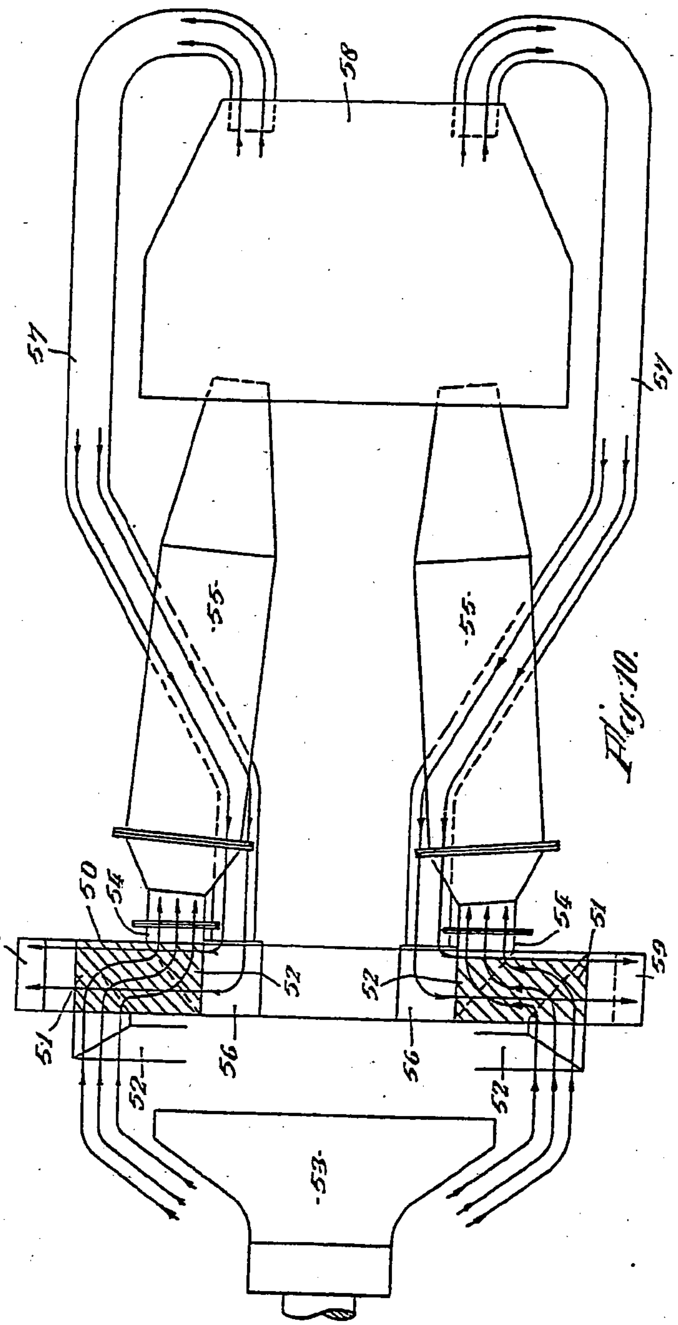


Fig. 10.

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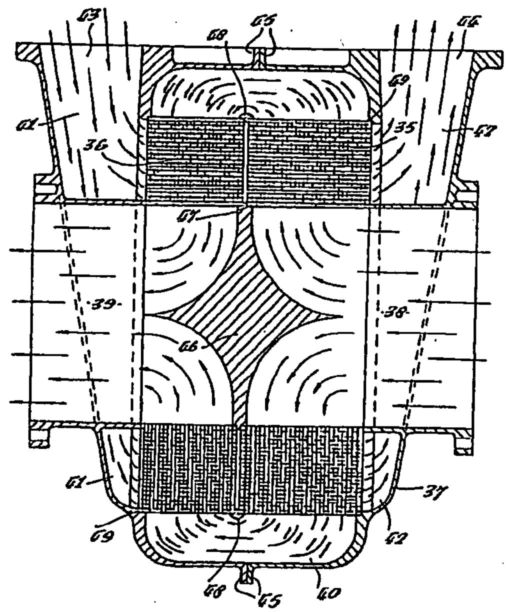
Sheets 5 & 6



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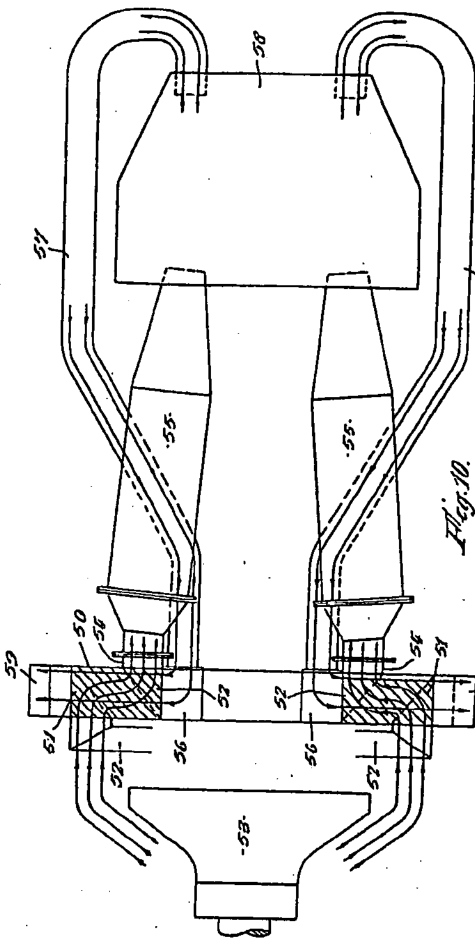

Fig. 10.